

## Safe from the Storm: Creating Climate-Resilient Health Care Facilities

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It was New York City, 29 October 2012. Hurricane Sandy forced the evacuation of more than 6,400 patients from six hospitals and 31 residential care facilities.<sup>1</sup> Among them was Bellevue, the nation's oldest public hospital, which saw its first sustained closure since opening in 1736.<sup>2</sup> The hardest hit was NYU Langone Medical Center, where patients were evacuated down a dark stairway after power systems failed.<sup>3</sup> The hospital suffered nearly \$1 billion in damages,<sup>4</sup> remained fully closed for two months, and went without an emergency room for a year and a half.<sup>4</sup> Perhaps remarkably, no patients died as a result of the closures and evacuations.<sup>5</sup>

In the aftermath of disaster, local municipalities typically reflect on what went right and what went wrong. New York City was no exception after Sandy, which caused some \$19 billion in economic losses across the five boroughs.<sup>6</sup> The city's new Building Resiliency Task Force subsequently translated lessons from the storm into building code modifications designed to reduce future losses from extreme weather events.<sup>7</sup>

But few of these improvements were targeted toward hospitals, says Robin Guenther, a New York City–based architect and expert on sustainable health care facilities. So she and colleague John Balbus, a senior advisor for public health with the National Institute of Environmental Health Sciences (NIEHS), decided to fill that gap.

### Special Responsibilities and Needs

Guenther and Balbus recognized that hospitals have special needs relative to many other buildings, just as they also have great responsibilities.<sup>8</sup> Hospitals consume more power and water than most other buildings and businesses, so disruptions in power and water supplies can have substantial impacts on operability. For access and supplies, they rely heavily on public transportation infrastructure, which can be shut down abruptly by a disaster.

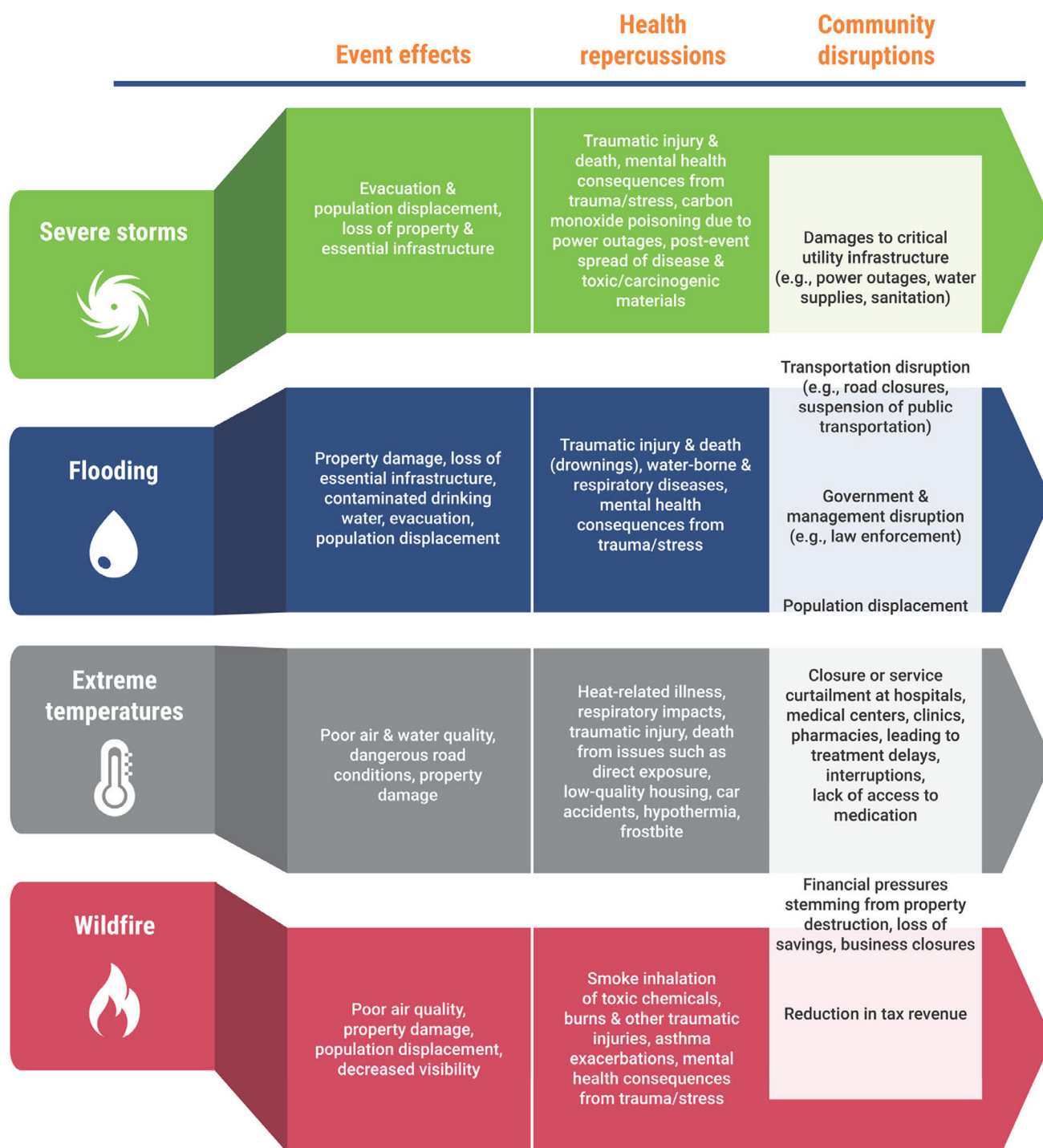
Given projected changes to global average temperatures, precipitation patterns, and sea levels in the coming decades, health care facilities can expect new and heightened threats from natural disasters and extreme weather.<sup>9</sup> But not all hospitals face the same future. For some it will include higher winds and greater flooding; for others it will be more droughts, heat waves, and wildfires. Still others see on the horizon more extreme cold or harsher winter storms.

Smarter design and construction practices—such as ground floors designed to take on floodwater and air systems that filter heavy smoke—could help hospitals do a better job of riding out natural disasters and wild weather in an era of climate change. More to the point, it could help them avoid evacuation (or at least minimize disruption), keep patients safe, and continue serving their communities at critically important times.



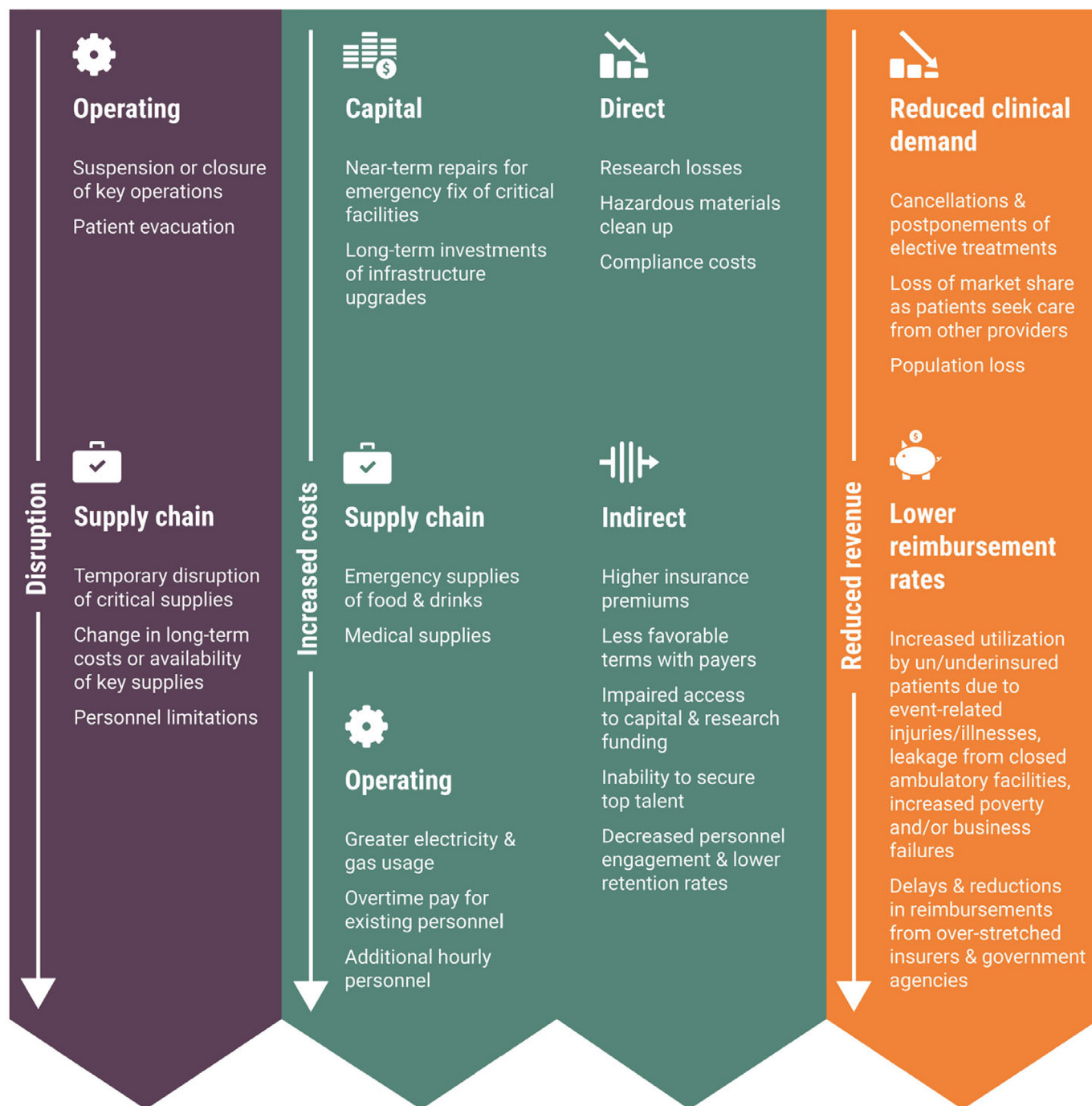
Patients were evacuated from the darkened NYU Langone Medical Center at the height of Hurricane Sandy on 29 October 2012. The hospital remained closed for two months after the storm, the emergency room even longer. Image: © Michael Heiman/Getty Images.

# The costs of being ill-prepared



According to the latest figures from the National Oceanic and Atmospheric Administration at the time of publication, in 2018 alone the United States has experienced 11 weather- and climate-related disasters costing more than \$1 billion each.<sup>35</sup> That number does not include Hurricane Michael. Events like these hit health care facilities' bottom line in multiple ways. Figure: © "Safe Haven in the Storm,"<sup>12</sup> Health Care Without Harm/PricewaterhouseCoopers Advisory Services LLC. (Continued next page.)

## The bottom line damages for health care



## Downward pressure on margin

(Figure continued.)

Existing hospitals were designed to last a long time. Thus, they are increasingly likely to fall short of safety codes and standards over the coming decades. Some of these challenges can be addressed through planning and training, but the quality of the building or campus itself is critical, Guenther says.

"It all calls into question hospital preparedness and whether [existing] code-mandated solutions are the right ones for the twenty-first century," Guenther says. "It's time for every health system in the country to take stock of that and get on top of it."

Guenther and Balbus channeled their thinking into a comprehensive guidance document called "Primary Protection: Enhancing Health Care Resilience for a Changing Climate."<sup>8</sup> Supported primarily by the U.S. Department of Health and Human Services (DHHS), the guidance was published in 2014.

One of its main points is that developers should use predictive climate models to set structural design criteria for hospitals and other health care facilities, and that these criteria should be applied to retrofits and new construction alike. The authors also advise that

hospitals lessen their reliance on external safeguards, such as levees, to protect them from the impacts of extreme weather. In addition, hospitals should reinforce and duplicate their backup power and water systems. They also should be prepared to serve as a regional-level resource during a disaster.

After preparing the guide, Guenther and Balbus went two steps further by creating what is known as the Sustainable and Climate-Resilient Health Care Facilities Toolkit and an accompanying series of checklists to help individual hospitals assess their own vulnerabilities and priorities. The toolkit includes the interactive Climate Explorer, which projects how local climate conditions may change in the relatively near future, based on existing global climate models. The entire package, including a revised version of the “Primary Protection” guidance, was released in 2015 and is available free of charge online.<sup>10</sup>

### Putting the Toolkit to Use

One early user of the DHHS toolkit was the Cleveland Clinic, an Ohio-based health care system with additional facilities in London, Toronto, Abu Dhabi, and multiple locations in Florida. The organization happened to be in the process of expanding its Weston, Florida, hospital when the toolkit was published.

The Cleveland Clinic ran a vulnerability assessment of the Weston site and learned that the frequency of so-called blue-sky flooding within the next 20 to 30 years as a result of sea-level rise. Blue-sky flooding is caused not by storms but by unusually high tides. Yet Weston is not a coastal town. Instead, it is located about 20 miles inland from Fort Lauderdale, adjacent to the Everglades, situated above a layer of porous limestone that allows groundwater to percolate up to the surface.<sup>11</sup> “We raised the floor of that facility just to mitigate future flood risk,” says Jon Utech, senior director of the Cleveland Clinic’s Office for a Healthy Environment.

The assessment also suggested that projected increases in the severity of thunderstorms and hurricanes called for stronger glass in the building. So the facility’s windows were upgraded to “missile-resistant,” which Utech says means strong enough to withstand a hit by a two-by-four flying at 175 miles per hour. Finally, the Cleveland Clinic built additional redundancy into the Weston hospital’s backup power system.

Closer to home in northeast Ohio, where the majority of the Cleveland Clinic’s footprint is found, the assessment indicated that tornadoes may become a greater threat by mid-century. In response, the Cleveland Clinic has stepped up staff training to respond to twisters and extreme wind, and it’s pilot testing a shatter-resistant film coating for windows.

The concept of climate resilience is catching on at hospitals across the country, says Lauren Koch, associate director of mitigation and resilience initiatives with the global nonprofit Health Care Without Harm (HCWH). “We’re starting to see this [concept] take off,” she says. “Since there have been a lot of extreme weather events, this is on the forefront of people’s minds. It is a tangible thing.”

But the toolkit is designed to get hospitals thinking about not only acute emergencies like hurricanes and wildfires, but also gradual shifts such as increasing average temperatures, says Jessica Wolff, climate and health program director for HCWH. “We hope that every time a hospital plans a remodel or construction of a new building, they consider climate projections.”

Wolff notes that securing funds for climate resilience often requires hospitals to make a business case for risk mitigation. Being ill prepared can be costly, according to a 2018 analysis by HCWH and Price WaterhouseCoopers Advisory Service LLC.<sup>12</sup> Disaster-related factors such as revenue loss and major emergency repairs chip away at a hospital’s profit margin. On the other hand, investments in preparedness, such as energy-efficient

infrastructure, may pay for themselves over time. Intangibles matter too: As the 2018 analysis points out, “Systems that respond well in catastrophic conditions boost the brand, differentiate from peers, and improve staff loyalty and recruitment.”

### Models of Resilience

Just as Guenther and Balbus’s “Primary Protection” guide followed on Sandy’s heels, it was also a direct response to shortfalls exposed by Hurricane Katrina seven years before. The guide is peppered with references to that fateful storm. It also includes discussions of two newer hospitals that applied lessons from Katrina and now serve as models of resilience for future projects.

First came Spaulding Rehabilitation Hospital in Boston. Already under construction when Sandy slammed into the East Coast, it became the first building on the city’s waterfront to account for projected sea-level rise. Guenther’s firm, Perkins+Will, served as lead architect, with she as its resident sustainability expert. Five years later, Spaulding is still widely acknowledged as one of the most climate-resilient hospitals in the United States.

The facility’s first floor is located 30 inches above the projected 500-year flood elevation, and all critical patient care functions are at least another floor up. The 132-bed hospital features roof-mounted mechanical and electrical infrastructure that will be safe from flooding. Inspired by Katrina, in which patients and staff were trapped in sweltering buildings with fixed-shut windows, the Spaulding facility’s windows can be opened, and a high-performance building envelope prevents extremely high or low indoor temperatures if the power goes out.

Building a hospital that so far exceeded federal, state, and local codes was not easy, says Boston architect Hubert Murray, who led sustainability efforts for Partners HealthCare, the network to which Spaulding belongs. “It took a bit of politics as well as engineering to actually get what we wanted,” Murray says. “Now people are coming from all over the country and even from other countries just to see the building.”

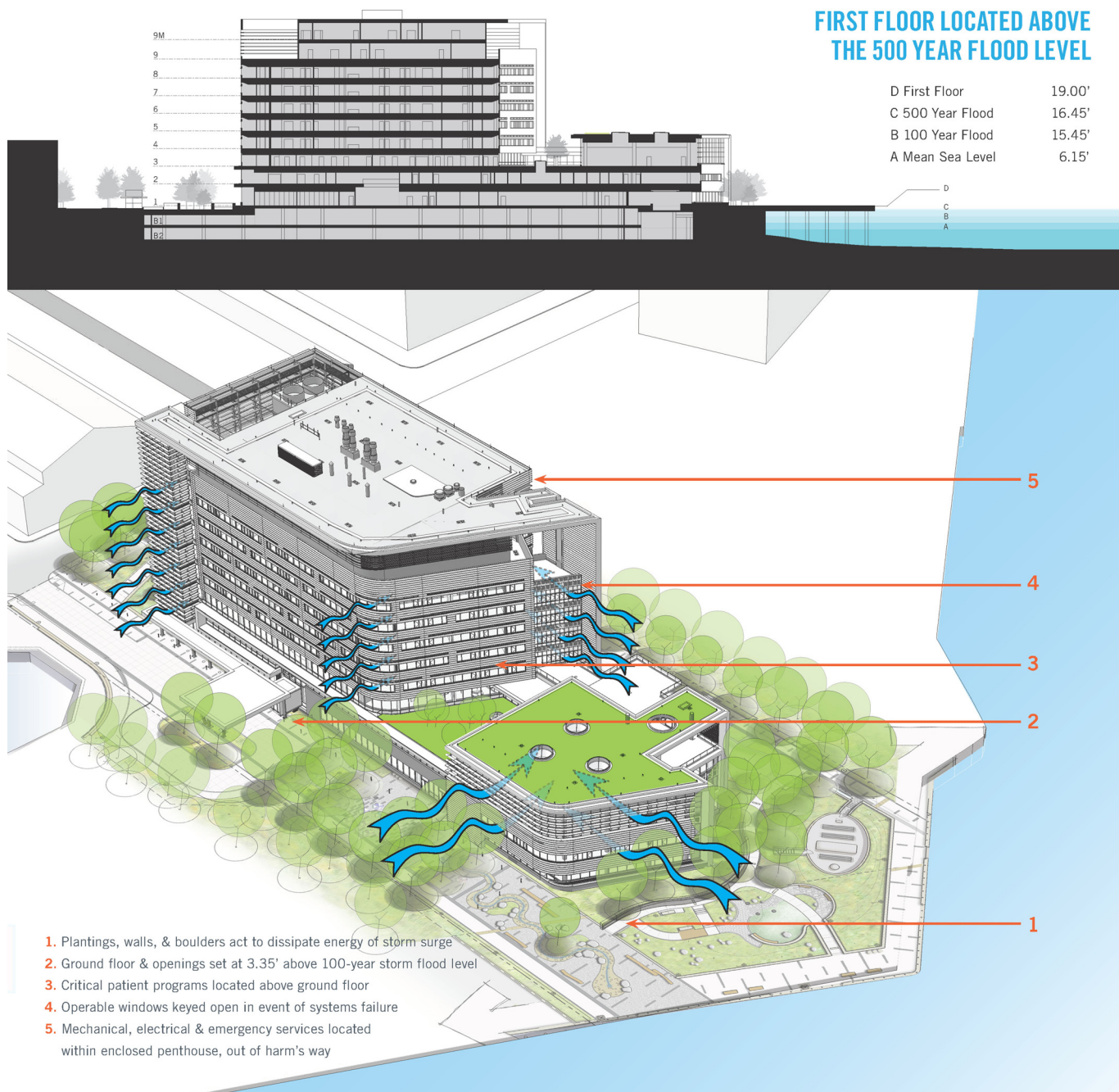
Back in New Orleans, Katrina’s lessons were also heeded by the architects of the city’s newest paragon of health care resilience, the Southeast Louisiana Veterans Health Care Center. Completed in 2016, this 1.7 million ft<sup>2</sup> campus replaced two hospitals closed by Katrina.<sup>13</sup>

The new hospital is prepared to go seven days without any outside support. It stocks supplies for up to 1,000 people and enough diesel fuel to power its generators at full strength. It has an on-site sewage treatment plant to process and hold a week’s worth of waste. And its rainwater collection system, with a capacity of more than a million gallons, reduces the use of city water for nonpotable needs during regular operations while providing a source of emergency water when the normal supply is interrupted.

The hospital is also designed to survive failure of the city’s levees—the source of so much damage after Katrina—with raised floor elevations and critical functions moved from harm’s way. Ambulances use a dedicated ramp that doubles as a boat launch.

### Additional Resources

The DHHS Sustainable and Climate-Resilient Health Care Facilities Toolkit is not the only resource for preparing hospitals for future disasters. Similar efforts have evolved in both Canada and the Caribbean in recent years.<sup>14</sup> The Ontario-based nonprofit Canadian Coalition for Green Health Care began developing a 78-question resiliency checklist in 2013. Later it added a mentoring program to guide facilities in assessing and increasing their resilience. Dozens of hospitals have used the checklist in recent years, says Kent Waddington, cofounding director and communications director for the coalition.<sup>15</sup>



Planning for Boston's Spaulding Rehabilitation Hospital began shortly after Hurricane Katrina hit the Gulf Coast in 2005, and many of its features reflect lessons learned from that storm. (Note: the blue arrows signify natural ventilation via operable windows.) During Hurricane Sandy in 2012, the resilient design proved its mettle: The elevated ground floor stayed dry at high tide, and the facility sustained minimal damage. Image: © Perkins+Will.

Meanwhile, the Pan American Health Organization (PAHO) is leading an effort to help vulnerable Caribbean hospitals prepare.<sup>16,17</sup> The health sector is heavily affected by climate change, says Ciro Ugarte, PAHO's director of emergency preparedness and disaster relief. But health facilities—especially the larger ones—also make a considerable contribution to the problem through high energy and water use. By reducing consumption and making operations more energy efficient, Ugarte says, hospitals both shrink their carbon footprint and increase self-sufficiency.

Some 300 hospitals in seven Caribbean countries have been assessed for weaknesses and inefficiencies since the PAHO program launched in 2011, Ugarte says. Many of these facilities have also benefited from building upgrades and retrofits, largely funded by the U.K. Department for International Development. More work is yet to come.

In 2015, the World Health Organization published its own guidance on resilient health care systems.<sup>18</sup> And two years later, the World Bank published a report that encourages a two-pronged approach much like those promoted by the PAHO and HCWH:

working simultaneously to slow climate change and to overcome the effects we cannot avoid.<sup>19</sup>

“A lot of work begins with mitigation,” says HCWH’s Wolff—reducing energy and waste to save money while limiting carbon emissions. “Resilience and mitigation work are really two sides of the same coin. If you use less energy, your generators will last longer if your grid goes down,” she says. “It becomes more real as these events become more and more frequent.”

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## Appendix: Bitter Experience

Hurricane Katrina, which struck the Gulf Coast in 2005, could be called the watershed moment for the movement toward resilient hospitals. The storm closed every hospital in New Orleans—some temporarily and some for good<sup>8</sup>—and stranded more than 1,800 patients inside.<sup>20</sup> Worse yet, it rendered many heartbreaking scenes within crippled, yet still occupied, hospitals in the days after the storm.

Inside Memorial Medical Center, for example, staff and patients threw furniture through fixed windows for relief from stinking, stifling air and 100-degree temperatures.<sup>20</sup> Lindy Boggs Medical Center lost power, water, and communications after the storm and soon ran out of critical supplies. And detailed reports later surfaced from Charity Hospital of family members fanning patients for hours in the oppressive heat, workers using buckets and bags as toilets, and doctors making rounds by flashlight.<sup>20</sup> Dozens died during the ordeal.<sup>20</sup>

Had hospitals known so many levees would fail in the storm and flood 80% of the city,<sup>21</sup> perhaps they would have elected to evacuate beforehand. But systemic regionwide oversights were

also to blame, according to Guenther and Balbus, even after the lessons of hurricanes Andrew in 1992 and George in 1998: “In many ways, “they wrote,” Katrina epitomized a failure to integrate available meteorological knowledge and engineering solutions on a timely basis to protect critical infrastructure, most especially hospitals, from known risk.”<sup>8</sup>

Hurricanes Sandy and Katrina are just two examples of severe storms impeding the work of major hospitals and their ability to provide care at the time they are needed most. There are many more in the United States alone.

In June 2001, Tropical Storm Allison caused \$2 billion worth of damage to Houston’s 700-acre Texas Medical Center.<sup>8</sup> In August 2017, flooding from Hurricane Harvey hit the East Houston Regional Medical Center so hard it never recovered.<sup>22</sup> Three weeks later, Hurricane Maria battered hospitals and interrupted health care across Puerto Rico,<sup>23</sup> causing a third of all storm-related deaths, according to one estimate.<sup>24</sup> And in September 2018, Hurricane Florence, by far the wettest tropical cyclone ever to hit the Carolinas,<sup>25</sup> closed dozens of hospitals and other health care facilities in its path.<sup>26</sup> Hurricane Michael followed on Florence’s heels, with damages still being assessed as this story went to press.

Storms are not the only climate-related disasters to interfere with health care. In October 2017, a fire that would soon become the most destructive in California history raced toward the city of Santa Rosa, population 175,000.<sup>27</sup> Two regional hospitals were in the path of the flames, and both opted to evacuate on a moment’s notice in the middle of the night.<sup>28</sup> Patients rolled on wheelchairs and gurneys across parking lots lit glowing red by fire toward ambulances and buses. The threat soon passed, but one hospital stayed empty for eight days<sup>29</sup> and the other for more than two weeks<sup>30</sup> while multiple fires and stifling smoke continued to threaten the region.



Sutter Santa Rosa Regional Hospital was one of two California hospitals that evacuated in the middle of the night as a wildfire approached on 8 October 2017. Climate-related disasters include more than the archetypal hurricane sweeping ashore—at the local level, climate change can influence the occurrence and intensity of wildfires, blizzards, blue-sky flooding, tornadoes, and other phenomena. Image: Courtesy CNN.

That same year, an unusually high volume of snowmelt outside remote Churchill, Canada, severed the local railroad, isolating the small town's only hospital.<sup>31</sup> Then, in January 2018, a massive mudslide in Central California was triggered by heavy rains. That disaster injured more than 160,<sup>32</sup> killed 21,<sup>33</sup> and cut off access to local hospitals. Six months later, another historic California wildfire forced the evacuation of rural Lake County's only trauma center.<sup>34</sup>

## References

- Health Care Without Harm (HCWH). 2017. *Resilience 2.0: Healthcare's Role in Anchoring Community Health and Resilience*. Reston, VA:Health Care Without Harm. <https://noharm-uscanada.org/sites/default/files/Resilience%202.0%20Boston%20-%20Healthcare%27s%20Role%20in%20Anchoring%20Community%20Resilience.pdf> [accessed 14 October 2018].
- Ofri D. 2012. A return to Bellevue after the storm. *The New York Times*, Well section, online edition, 27 November 2012. <https://well.blogs.nytimes.com/2012/11/26/a-return-to-bellevue-after-the-storm/> [accessed 14 October 2018].
- Remnick D. 2012. Leaving Langone: one story. *The New Yorker*, News Desk section, online edition, 30 October 2012. <https://www.newyorker.com/news/news-desk/leaving-langone-one-story> [accessed 14 October 2018].
- Hartocollis A. 2014. NYU Langone reopens emergency room that was closed by Hurricane Sandy. *The New York Times*, New York section, online edition, 25 September 2014. <https://www.nytimes.com/2014/04/25/nyregion/nyu-langone-reopens-emergency-room-that-was-closed-by-hurricane-sandy.html> [accessed 14 October 2018].
- Centers for Disease Control and Prevention. 2012. Deaths associated with Hurricane Sandy—October–November 2012. *MMWR Morb Mortal Wkly Rep* 62(20):393–397, PMID: 23698603.
- Russ H. 2012. New York, New Jersey put \$71 billion price tag on Sandy. *Reuters*, U.S. section, 26 November 2012. <https://www.reuters.com/article/us-storm-sandy-cost-nyc/new-york-new-jersey-put-71-billion-price-tag-on-sandy-idUSBRE8AP0S220121127> [accessed 14 October 2018].
- Urban Green Council. 2016. Building Resiliency Task Force [website]. <https://www.urbangreencouncil.org/content/projects/building-resiliency-task-force> [accessed 14 October 2018].
- Guenther R, Balbus J. 2014. *Primary Protection: Enhancing Health Care Resilience for a Changing Climate*. Washington, DC:U.S. Department of Health and Human Services. <https://toolkit.climate.gov/sites/default/files/SCRHCF1%20Best%20Practices%20Report%20final2%202014%20Web.pdf> [accessed 14 October 2018].
- U.S. Environmental Protection Agency. 2016. Climate Change Science: Future of Climate Change [website]. [https://19january2017snapshot.epa.gov/climate-change-science/future-climate-change\\_.html](https://19january2017snapshot.epa.gov/climate-change-science/future-climate-change_.html) [accessed 14 October 2018].
- U.S. Global Change Research Program. 2016. Building Health Care Sector Resilience [website]. <https://toolkit.climate.gov/topics/human-health/building-climate-resilience-health-sector> [accessed 14 October 2018].
- Kolbert E. 2015. The siege of Miami. *The New Yorker*, online edition, 21 December 2015. <https://www.newyorker.com/magazine/2015/12/21/the-siege-of-miami> [accessed 14 October 2018].
- HCWH. 2018. *Safe Haven in the Storm: Protecting Lives and Margins with Climate-Smart Health Care*. Reston, VA:Health Care Without Harm US. <https://noharm-uscanada.org/sites/default/files/documents-files/5146/Safe%20Haven.pdf> [accessed 14 October 2018].
- U.S. Global Change Research Program. 2018. After Katrina, Health Care Facility's Infrastructure Planned to Withstand Future Flooding [website]. <https://toolkit.climate.gov/case-studies/after-katrina-health-care-facilities-infrastructure-planned-withstand-future-flooding> [accessed 14 October 2018].
- Balbus J, Berry P, Brett M, Jagnarine-Azan S, Soares A, Ugarte C, et al. 2016. Enhancing the sustainability and climate resiliency of health care facilities: a comparison of initiatives and toolkits. *Rev Panam Salud Publica* 40(3):174–180, PMID: 27991975.
- Canadian Coalition for Green Health Care. 2016. Climate Change Resiliency Monitoring [website]. <http://greenhealthcare.ca/mentoring/> [accessed 14 October 2018].
- Pan American Health Organization (PAHO). 2015. PAHO/WHO Promotes Safe, Green and "Smart" Hospitals in the Caribbean [press release]. Washington, DC:Pan American Health Organization (10 September 2015). [http://www.paho.org/hq/index.php?option=com\\_content&view=article&id=11225:pahowho-promotes-safe-green-and-smart-hospitals-in-the-caribbean&Itemid=1926&lang=en](http://www.paho.org/hq/index.php?option=com_content&view=article&id=11225:pahowho-promotes-safe-green-and-smart-hospitals-in-the-caribbean&Itemid=1926&lang=en) [accessed 14 October 2018].
- PAHO. 2018. Smart Hospitals [website]. [http://www.paho.org/disasters/index.php?option=com\\_content&view=article&id=3660:hospitales-inteligentes&Itemid=911&lang=en](http://www.paho.org/disasters/index.php?option=com_content&view=article&id=3660:hospitales-inteligentes&Itemid=911&lang=en) [accessed 14 October 2018].
- World Health Organization. 2015. *Operational Framework for Building Climate Resilient Health Systems*. Geneva, Switzerland:World Health Organization. <http://www.who.int/globalchange/publications/building-climate-resilient-health-systems/en/> [accessed 14 October 2018].
- Bouley T, Roschnik S, Karliner J, Wilburn S, Slotterback S, Guenther R, et al. 2017. *Climate-Smart Healthcare: Low-Carbon and Resilience Strategies for the Health Sector*. Washington, DC:World Bank Group. <http://documents.worldbank.org/curated/en/322251495434571418/Climate-smart-healthcare-low-carbon-and-resilience-strategies-for-the-health-sector> [accessed 14 October 2018].
- Gray BH, Hebert K. 2016. *After Katrina: Hospitals in Hurricane Katrina: Challenges Facing Custodial Institutions in a Disaster*. Washington, DC:Urban Institute. <https://www.urban.org/sites/default/files/publication/50896/411348-Hospitals-in-Hurricane-Katrina.PDF> [accessed 14 October 2018].
- Maldonado C. 2015. Katrina fact-check: guesstimate of Katrina's flooding in New Orleans was correct. *The Lens*, Environment section, online edition, 20 July 2015. <https://thelensnola.org/2015/07/20/katrina-fact-check-guesstimate-of-katrinass-flooding-in-new-orleans-was-correct/> [accessed 14 October 2018].
- Deam J, Ackerman T. 2017. Harvey-damaged East Houston Regional Medical Center will close. *The Houston Chronicle*, online edition, 10 November 2017. <https://www.chron.com/business/medical/article/Harvey-damaged-East-Houston-Regional-Medical-12345399.php> [accessed 14 October 2018].
- Respaut R, Graham D. 2017. Battered Puerto Rico hospitals on life support after Hurricane Maria. *Reuters*, World News section, 24 September 2017. <https://www.reuters.com/article/us-storm-maria-puertorico-hospitals/battered-puerto-rico-hospitals-on-life-support-after-hurricane-maria-idUSKCN1BZ13S> [accessed 14 October 2018].
- Kishore N, Marqués D, Mahmud A, Kiang MV, Rodriguez I, Fuller A, et al. 2018. Mortality in Puerto Rico after Hurricane Maria. *N Engl J Med* 379(2):162–170, PMID: 29809109, <https://doi.org/10.1056/NEJMsa1803972>.
- Erdman J. 2018. Florence sets preliminary North Carolina and South Carolina tropical cyclone rain records; third, fourth states to do so in 12 months. *The Weather Channel*, Hurricane Central section, 15 September 2018. <https://weather.com/storms/hurricane/news/2018-09-15-florence-north-carolina-tropical-rain-record> [accessed 14 October 2018].
- Masterson L. 2018. Hurricane Florence forces hospital closures, patient transfers. *Healthcare Dive*, 17 September 2018. <https://www.healthcaredive.com/news/hurricane-florence-forces-hospital-closures-patient-transfers/532488/> [accessed 14 October 2018].
- Tierney L. 2018. The grim scope of 2017's California wildfire season is now clear. The danger's not over. *The Washington Post*, National section, online edition, 4 January 2018. <https://www.washingtonpost.com/graphics/2017/national/california-wildfires-comparison> [accessed 14 October 2018].
- Nedelman M. 2017. Hospitals evacuated and many injured as wildfires ravage Northern California. *CNN*, Health section, 9 October 2017. <https://www.cnn.com/2017/10/09/health/california-wildfires-hospitals-evacuation/index.html> [accessed 14 October 2018].
- Espinoza M. 2017. Sutter hospital in Santa Rosa reopens eight days after being closed by firestorm. *The Press Democrat*, online edition, 17 October 2017. <http://www.pressdemocrat.com/news/7534819-181/sutter-hospital-in-santa-rosa> [accessed 14 October 2018].
- Espinoza M. 2017. Kaiser Permanente in Santa Rosa reopens hospital, 17 days after fires forced closure. *The Press Democrat*, online edition, 25 October 2017. <http://www.pressdemocrat.com/news/7564555-181/kaiser-permanente-in-santa-rosa> [accessed 14 October 2018].
- Porter C. 2017. Canadian town, isolated after losing rail link, 'feels held hostage.' *The New York Times*, Canada section, online edition, 31 August 2017. <https://www.nytimes.com/2017/08/30/world/canada/canada-climate-change-arctic.html> [accessed 14 October 2018].
- BBC. 2018. California: thirteen dead in Montecito rains and mudslides. *BBC News*, US & Canada section, 10 January 2018. <http://www.bbc.com/news/world-us-canada-42624408> [accessed 14 October 2018].
- Dolan J. 2018. Search teams find 21st victim of Montecito mudslide. *The Los Angeles Times*, Local section, online edition, 21 January 2018. <http://www.latimes.com/local/lanow/la-me-montecito-death-toll-20180121-story.html> [accessed 14 October 2018].
- Lake County News Reports. 2018. Sutter Lakeside Hospital reopens; Mendocino Complex had forced facility closure. *Lake County News*, News section, online edition, 11 August 2018. <http://www.lakeconews.com/index.php/news/57332-sutter-lakeside-hospital-reopens-facility-had-been-closed-due-to-mendocino-complex> [accessed 14 October 2018].
- National Oceanic and Atmospheric Administration. 2018. Billion-Dollar Weather and Climate Disasters: Overview [website]. <https://www.ncdc.noaa.gov/billions/overview> [accessed 14 October 2018].